Constellation-X Hard X-ray Telescope Development Status and Projected Performance

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for the
Constellation-X Hard X-ray Telescope Working Group

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Outline

- Review of HXT performance requirements
- Review of technical approach
- Technology development status
  - multilayers
  - mirrors
  - detectors
- Performance calculations
  - background
  - effective area
  - performance projections
- Options for enhancements

Constellation-X HXT Requirements

Baseline HXT Requirements	
Effective Area	$\geq$ 1500 cm^2 (6 - 40 keV)
Signal/Background	$\geq$ 1 for T_{obs} > 2 x 10^4 s
FOV	$\geq$ 8 arcmin (6 - 40 keV)
Angular resolution	$\leq$ 1 arcmin HPD
$\Delta E/E$	$\leq$ 20% (6 - 30 keV)
Desirable Performance Enhancements	
Signal/Background	$\geq$ 1 for T_{obs} > 2 x 10^4 s
Effective Area/	$\geq$ 1500 cm^2 (6 - 40 keV)
Bandpass	extend to 1 keV
Angular resolution	$\leq$ 1 arcmin HPD
$\Delta E/E$	$\leq$ 5% at 40 keV
Mechanical Envelope	
Total Mass/Satellite	$\leq$ 250 kg
Geometric Aperture	< 0.75 m^2
Focal Length	10 meters

- Match spectroscopic sensitivity of SXT for high-energy continuum observations

- Map non-thermal emission in extended sources

Baseline Technical Approach

Extending focusing to high energies:

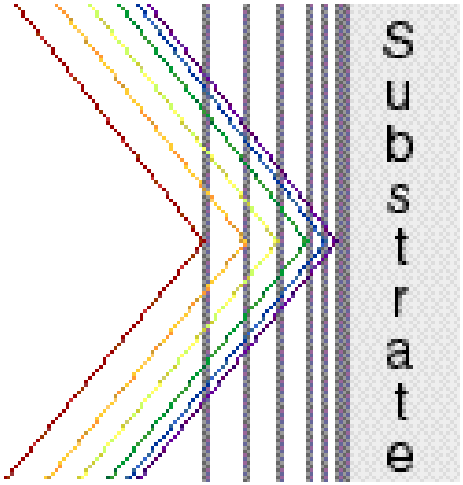
$$\gamma_{max} \sim 1/E$$

1) Utilize small focal ratios (r/f)

small radius optics, long focal length, multiple modules

2) Increase γ_{max} for given r/f

graded multilayer coatings



Con-X HXT: Graded multilayer Wolter-I (or conical approx.) telescopes with imaging solid state detectors.

Technology Status - Multilayers

Depth-graded multilayer parameters:

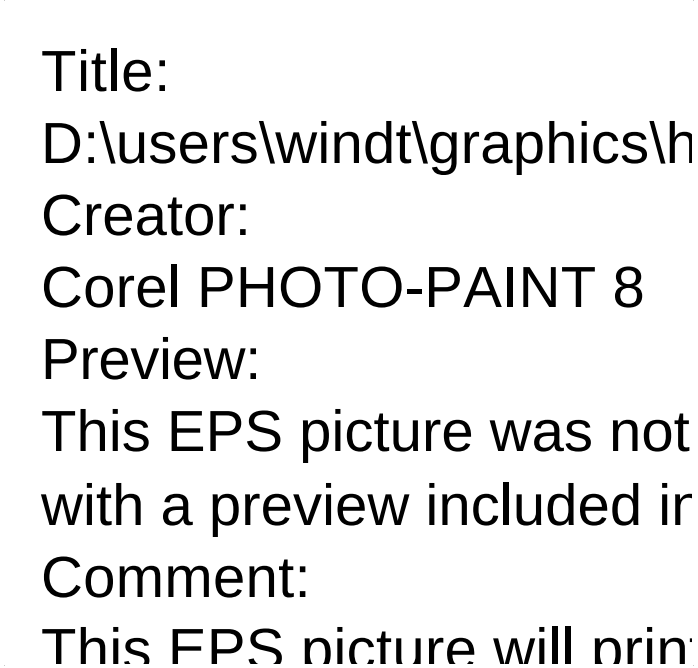
Minimum period	20 Angstroms
Max. # of layer pairs	500
Typical # layers	200
Material	W/Si or Pt/C

Progress on:

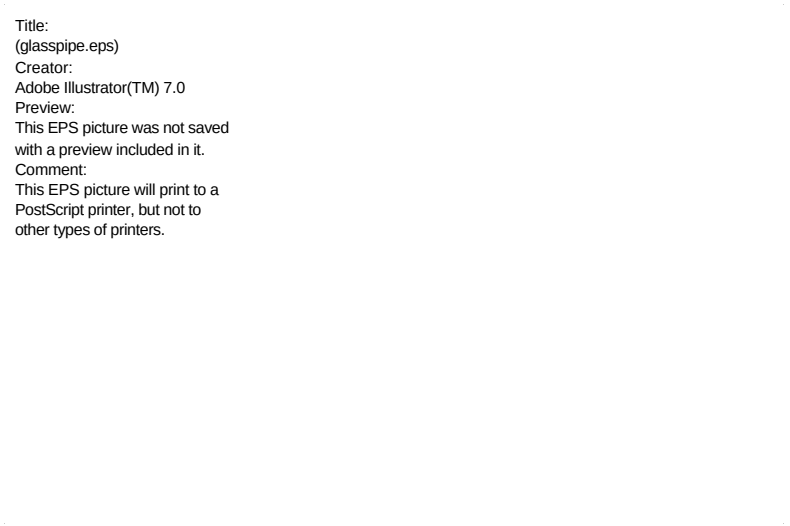
- Film growth and stability testing
- Deposition on curved optics
  - interior coatings
  - uniformity
- Film replication

Technology Status - Multilayers

Deposition on curved optics:



Graded multilayers on formed glass shells (Columbia/Caltech/DSRI/Lucent)



Multilayer coated on inside of cylinder (SAO)

Technology Status - Multilayers

Replication of multilayers:

Deposition onto mandrel - pull off onto substrate

Replication onto epoxy/Al foil (GSFC)

avoids deposition onto epoxy surface

Deposition of Ni substrate on top (U. Brera)

allows coatings to be applied to interiors of small-radius integral substrates

Progress: Mirrors

Substrates:

- Segmented optics (ASCA, ASTRO-E)
  - each 2-bounce shell assembled from 8 - 12 segments
  - coatings can be applied directly using planar magnetrons
  - low-density substrates can meet mass/resolution

- Integral replica shells (XMM)
  - fewer optics to align
  - exceed angular resolution specification but require thinner shells/lower density to achieve mass limit
  - require replication or interior deposition of multilayer

Progress: Mirrors

Con-X HXT

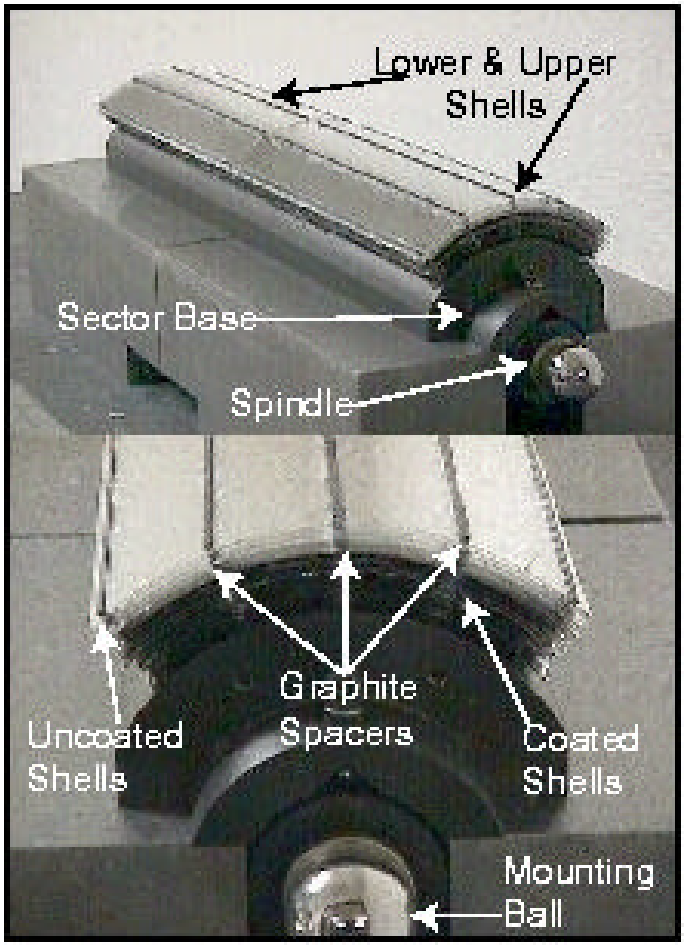
Segmented shells:

Epoxy-replicated Al foils

- Replication of multilayers demonstrated
- Can meet mass limit

Thermally-formed glass microsheet

- Demonstrated smooth surface for direct ml deposition
- Acceptable uniformity using planar magnetrons
- 15” figure measured in X-ray for individual shells
- Can meet mass limit with current thickness and materials

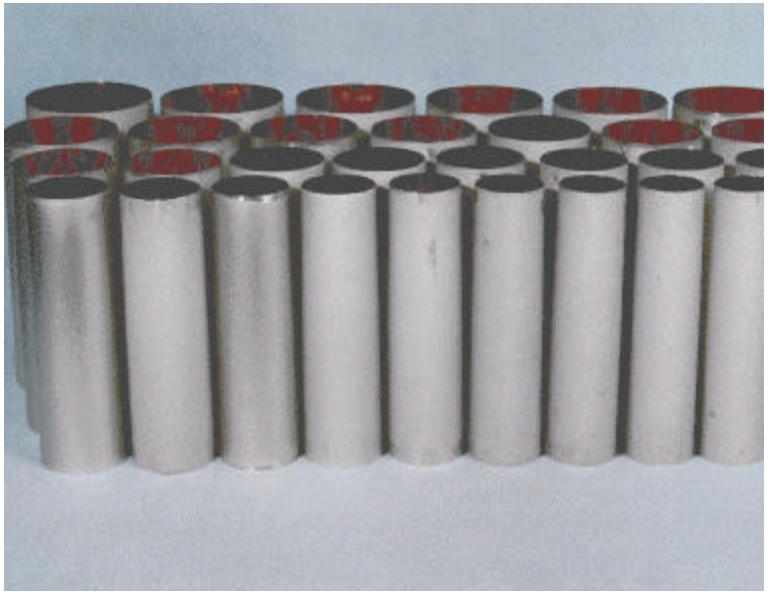


Formed glass prototype
(Columbia/DSRI/CIT/Lucent)

Progress: Mirrors

Integral-replica shells:

- Sputtering system developed for interior coating (SAO)
- Replication of ml (deposition onto mandrel) under development (Northwestern, Brera).
- Requires mass reduction - thinner shells (100 micron) - progress on new alloys relevant



SAX replica shells

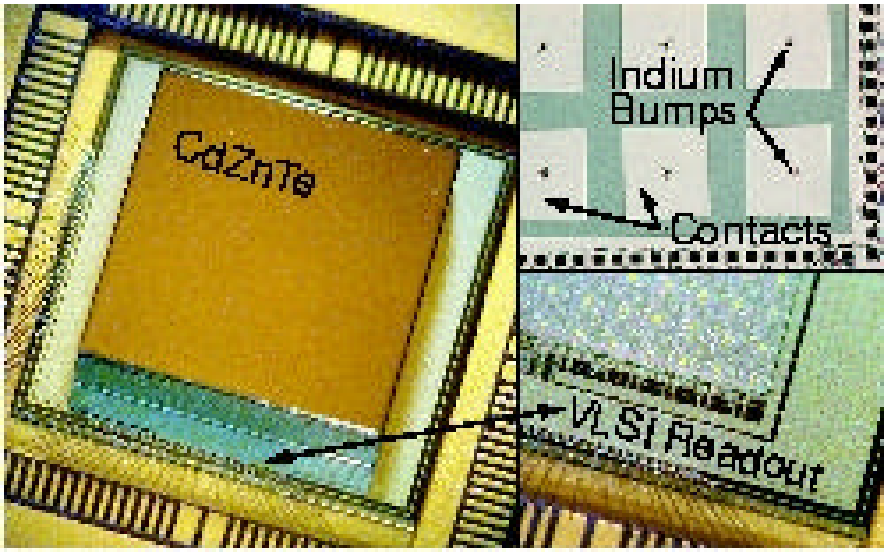
Progress: Detectors

Requirements:

ΔX	< 730 μm (10 meter focal length)
ΔE/E	< 20% FWHM (6 - 30 keV), < 10% (E > 30 keV)
Energy range	6 - 40 keV
Diameter	2.3 cm (minimum)
QE	> 90% 6 - 40 keV (including K escape events)
Background	< 2 x 10^{-4} cts/cm^2/s/keV

Primary option: Actively-shielded CdZnTe pixel detector

Being considered as a backup: Stacked Silicon strip detectors



Progress: Detectors

Material uniformity has been problematic

IR imaging and X-ray scanning at GSFC has yielded defect-free 1-inch wafers

Until recently low-energy thresholds on CdZnTe/ASIC hybrids have been ~15 keV, and energy resolution typically 3 - 5 keV @ 60 keV

Fully-functional low-noise custom CMOS ASIC (650 μm pixels) developed and demonstrated in hybrid(CIT)

-- threshold < 2 keV

-- 390 eV FWHM (18 keV), 550 eV FWHM (60 keV) (collimated beam)

-- demonstration of imaging performance/event reconstruction

-- QE measurements at E < 20 keV still required.

Progress: Detectors

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HEFT pixel detector spectrum (CIT/Columbia/DSRI)

Projected Performance: Background Calculations

L2 Orbit Background Calculation (SAIC/MSFC):

2 cm thick BGO well, 31 cm high, 2.5 cm diameter
1 mm thick CdZnTe detector

Internal background components:

Shield activation	7×10^{-5} cts/cm^2/s/keV
CZT activation	7×10^{-6} cts/cm^2/s/keV
CGC prompt	3×10^{-6} cts/cm^2/s/keV
total internal	8×10^{-5} cts/cm^2/s/keV

Projected Performance: Baseline Design

Telescope

focal length	10 meters
# satellites	4
mirrors/satellite	3

Multilayer

material	W/Si
minimum period	20 Angstroms
max. # layers	500

Optics:	**glass**	**nickel**
minimum radius	3 cm	6 cm
maximum radius	20 cm	20 cm
shell length	25 cm	40 cm
shell thickness	300 μm	100 μm
number of shells	149	82
mass/satellite	190 kg	250 kg

Projected Performance: Effective Area

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